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Forensic implications of carnivore scavenging on human remains recovered from outdoor locations in Greece

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ABSTRACT

Mammalian carnivores rank among the most common scavengers of human remains. The present study discusses the forensic implications that carnivore scavenging had on human remains recovered from outdoor locations in Greece, and reviews the current literature on this subject. The forensic anthropological investigation indicated that carnivores were able to disarticulate and scatter body parts and personal effects over the recovery area, destroy skeletal elements and affect their survival, and alter or destroy indicators related with the cause and manner of death. In one case, scattering of bones over a considerable distance compromised the recovery efforts, causing later a problem in re-associating the skeletons. Other taphonomic factors than scavenging such as rolling of skeletal elements may be also responsible for the movement of bones. Carnivore scavenging was also responsible for the production of tooth marks on bone, and for bone removal especially noted on the articular ends of long bones. Matching different bone alterations with such activity is of vital importance since as it was seen carnivore scavenging can confound the interpretation of perimortem skeletal trauma.

1. Introduction

Scavenging of human bodies by a variety of mammalian and non-mammalian animals is a well-known phenomenon in forensic pathology that has been documented in a number of studies.[1–3] Among the mammalian animals carnivores are the most common scavengers of human remains.

Carnivore scavenging in the early postmortem period results in soft tissue injuries identified by their ragged edges and by characteristic punctures caused by the canine teeth.[4–6] Skeletonized bodies exposed on the surface for long periods or buried in shallow graves are also attacked by carnivorous animals.[7,8] Since postmortem disturbance of human remains extends beyond the production of characteristic tooth marks on bone,[9] a better understanding of such activity can prove to be of great value to forensic death investigators.

The present study aims to investigate the forensic implications that carnivore scavenging had on human remains in four cases submitted to the Laboratory of Forensic Medicine and Toxicology, Medical School, University of Athens, Greece for anthropological evaluation.

2. Case reports

2.1. Case 1

A mostly disarticulated human skeleton was recovered in a steep-sided ravine. A survey of the area by the local police failed to recover all the skeletal elements. According to investigators the bones of the skeleton were scattered over a 15-m radius. In addition to the skeletal elements, several articles of clothing including a long-sleeved shirt and blue jeans, female underwear and sport shoes were found in the area. A pair of socks containing foot bones was found in each sport shoe.

Forensic anthropological analysis revealed that the remains belonged to a Mongoloid female, 30–34 years old with a living stature of 149 ± 3.27 cm. The remains were almost skeletonized with only dried soft tissue adhering to the occipital scalp of the cranium and some of the joint surfaces. Linear enamel hypoplasia was found on the anterior teeth of the upper and lower dentition, indicating a cessation of their growth and development during early adulthood. Fillings were also in evidence on some maxillary and mandibular teeth. Perimortem fractures were observed on the skull and on the 3rd, 4th and 6th left ribs, indicating a possible fall of the victim from height. Signs of animal scavenging were present on certain bones. The vertebral body of T12 was chewed with cancellus bone exposed, while its right transverse process was broken off. Both humeri showed carnivore damage on the heads,

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and on the medial and lateral epicondyles. The left ulna survived as "cylinder" with both articular ends destroyed. The heads of the first through fourth metacarpals of the right hand had been also subjected to gnawing (Fig. 1). Femora were attacked at the head and both condyles. Chewing of the left tibia involved the margins of the lateral condyle.

Comparison of the remains with antemortem dental records (panoramic X-ray) confirmed the anthropological analysis. The victim had been exposed to the surface for approximately 1-year. The remains were returned to the family at the close of the investigation and were later cremated.

2.2. Case 2

A partially skeletonized body was found in a forested area by a passing shepherd. According to police the body was lying in a supine position, while the area where had rested was downsloped having a 75% inclination. The remains were largely disturbed by scavengers. Several body parts and various personal effects were scattered within a 3-m radius from the main body location. Human hair masses and a wristwatch were located 1-m upslope from the body. The articulated right arm was found 1.90 m further upslope. The skull and the articulated mandible were found 1.20 m downslope from where the body had rested, while the articulated right lower leg including the foot was recovered 3.10 m away from the remains. Remnants of clothing were also scattered around the recovery area.

The anthropological analysis revealed that the remains originated from a 23–28 year old white male with a living stature of 166 ± 3.94 cm. A considerable amount of mummified skin and ligamentous tissue was associated with the remains. Both lower legs and feet were completely mummified. Pathology included antemortem tooth loss and several caries on the upper and lower dentition. Gross and microscopical examination of the remains failed to reveal any evidence of perimortem trauma. There was no apparent evidence for the cause and manner of death. Bone damage due to scavenging was noted on certain bones. Axial skeletal elements were undamaged except from the sacrum, which was chewed away at the inferior end. The sternal ends of the ribs were gnawed with crushed and splintered margins. The sternum was broken off at the inferior end of the body. The right clavicle was chewed away at the acromial end. Both scapulae showed gnawing damage at the inferior angle. The heads of the 4th and 5th metacarpals of both hands were subjected to scavenging. The right innominate bone was gnawed at the iliac crest. All the metatarsals of the mummified left foot were completely exposed and gnawed at the distal ends (Fig. 2). In addition, the phalanges of both feet were absent.

Fig. 1. Carnivore damage on the distal metacarpals of the right hand (arrows).

Fig. 2. Carnivore damage on the distal metatarsals of the mummified left foot.

A possible identification of the body was not feasible due to the lack of any antemortem dental records and radiographs. It was roughly estimated that the remains had been exposed for at least 6 months.

2.3. Case 3

Human skeletal remains were recovered in a forested ravine by a hunter. A survey of the area revealed that the remains were largely disturbed and scattered over an approximately 200-m radius. Several articles of clothing including two pairs of blue jeans, a female swimsuit and a sock with foot bones inside were also found in the area. Due to the incomplete and commingled nature of the remains, the exact number of individuals represented was not possible to be estimated at the scene.

The anthropological examination of the recovered bones indicated that they belonged to two individuals. The above calculation was based on the count of the most abundant skeletal element, taking into account its anatomical frequency, and the number of either left or right elements. Individuals were represented by mostly disarticulated bones covered with remnants of ligamentous tissue, especially at joint surfaces, and partially articulated skeletal material. The L2–L5 and the sacrum of the first individual were still attached by the remaining intervertebral discs. The same was seen on L1, L2 and L3 of the second individual. The remains of the first individual belonged to a white male, 28–33 years old with a living stature of 177 ± 3.94 cm. Pathology included antemortem tooth loss of a maxillary tooth and unilateral sacralization of L5. Perimortem oblique fractures were observed on the vertebral ends of the 6th and 8th left ribs. The second individual was that of a white female, 34–39 years old with a living stature of 161 ± 3.94 cm. A number of perimortem fractures were displayed on the skeleton. The mandible was fractured at the left ascending ramus. An avulsion fracture involving the superior angle was seen in the right scapula. Fractures of the right transverse processes were noticed on T12, L1, L2 and L3. The 3rd right rib displayed a transverse fracture on its lateral curvature. Fracture of both pubic rami was present in the right innominate bone.

Animal scavenging activity was responsible for the production of tooth marks on the recovered bones of both individuals. The axial skeletal elements of the first individual including the L4 and sacrum were gnawed at the anterior aspect of the body and at the facet for coccyx respectively. Minor damage was present at the

sternal end of the right 3rd rib. Both scapulae were gnawed at the acromion, coracoid process and inferior angle. Partial removal of the head associated with puncture marks was noted on the right humerus of the second individual. Medial epicondyle and both capitulum and trochlea were also involved. In the first individual, destruction of the left ulna was noted at the olecranon process, while the right radius was chewed at the proximal end. Primary areas of gnawing to the majority of the recovered innominate bones were the iliac crest and ischial tuberosity. Pits and punctures were also visible close to the margins of the damaged areas. Gnawing damage on the right innominate of the second individual altered the morphology of the perimortem fracture seen on the inferior ramus of pubis (Fig. 3). All the femora had been subjected to gnawing. Destruction and deep furrowing associated with puncture marks were noted on the head of the right femur of the second individual (Fig. 4). Greater trochanter and both medial and lateral condyles were also involved. The most affected sites on the tibiae were the margins of both condyles and the tuberosity. The left fibula was chewed on both articular ends in both individuals.

Although patterns of vertical deceleration injury were visible on both individuals, certain perimortem injuries may have been inflicted by scavengers. Since the police had no reports of anyone missing in the area, the identification of the remains was not possible. It was roughly estimated that both individuals had been exposed for approximately one and a half years.

2.4. Case 4

A disarticulated human skeleton was found close to a riverside. All the skeletal elements were recovered in the immediate vicinity of the main bone concentration, while some of them were partially covered with loose material brought down by the river. A degraded pair of shorts was found in association with the remains.

A full anthropological analysis was undertaken. The skeleton represented a white male, 65–75 years of age with a living stature of 170 ± 3.94 cm. The remains were completely skeletonized with only traces of ligamentous tissue adhering to some joint surfaces. Antemortem pathological changes included temporomandibular joint disease, slight degenerative changes to shoulder, elbow and left knee joints, and moderate degenerative changes to the lower thoracic and lumbar spine. Slight osteoarthritis was also present on the right 1st, 2nd and 3rd metacarpals. A healed fracture was displayed at the sternal end of the right 6th rib. No other skeletal injuries that could have been related to death were noted. Postmortem alterations included whitening of certain bones due to sun exposure and scavenging damage. Bone removal associated with puncture marks was noted on both condyles of the mandible. Ribs were subjected to scavenging on both proximal and distal ends, which appeared chewed away with splintered margins (Fig. 5). The right scapula was attacked at the acromion. The proximal ends of the right 3rd and the left 5th metacarpals were also gnawed by scavengers. The proximal end of the right 3rd metacarpal was broken off presenting a typical "channeled" breakage (Fig. 6).

Forensic anthropological analysis and antemortem medical data provided the necessary information to help establish a positive identification. The remains belonged to a psychiatric hospital patient who had been reported missing 5 years ago.

Fig. 4. Destruction and deep furrowing (arrow) associated with puncture marks (outlined arrow) on the head of the right femur.

3. Discussion

The present study has considered some of the effects that carnivores had on human remains recovered from outdoor locations in Greece. Carnivores can cause problems in the forensic investigation of skeletonized remains due to their ability to: (1) disarticulate and scatter body parts, (2) alter skeletal elements, (3) affect survivorship of skeletal elements, and (4) alter or destroy

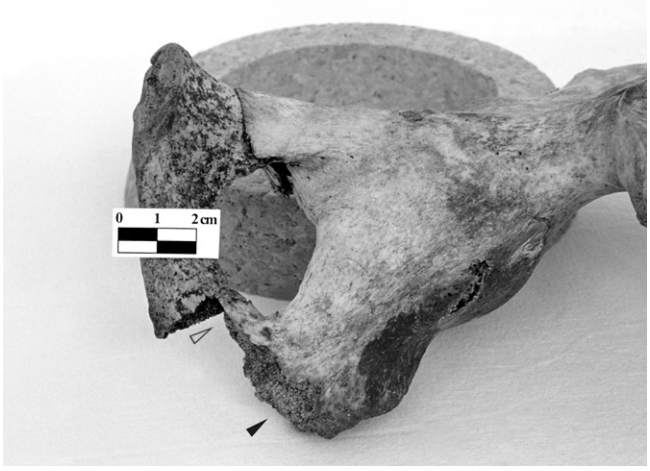

Fig. 3. Carnivore damage on the ischial tuberosity of the right innominate (arrow). Note that gnawing damage altered the morphology of the perimortem fracture seen on the inferior ramus of pubis (outlined arrow).

Fig. 5. Gnawing damage on both proximal and distal ends of the left 2nd rib (inferior view). Note the splintered margins on the distal end.

Fig. 6. Channeled breakage on the proximal end of the right 3rd metacarpal (arrow).

indicators related to the cause and manner of death and/or personal identification.

Factors dictated by the remains, the scavenger, and environment affect the extent and type of damage to soft tissue and bone, and the sequence in which body parts or skeletal elements are disarticulated and scattered. All of these interactive factors are profoundly influenced by the manner of disposition of the remains.[10]

3.1. Disarticulation and scattering of human remains

Carnivores are capable of inflicting disarticulation and scattering of human remains. Field research on modifications of road-killed deer carcasses by wolves has shown that the pattern of disarticulation and scattering of mammalian skeletons is very predictable.[11] Human remains exposed on the surface can also become disarticulated in a pattern similar to other mammals.[12,13] Haglund et al. have documented the stages of sequential disarticulation due to canid scavenging by examining 46 partially to fully skeletonized human remains.[14] They have stated that the pattern of disarticulation depends on the natural intrinsic properties of the bone with the surrounding joint attachments, and the relative amounts of easily decomposable and more resistant tissue. Disarticulation is facilitated by advanced decomposition while mummification may slow down the process.[15–17] Mummification also retains skeletal elements in anatomical position, so once disarticulated, body parts such as the upper and lower extremities can be transported as a unit.[14,18,19] This could explain why the right arm and the lower leg in Case 2 were found articulated and away from the initial body location.

The ability to move a corpse depends on the weight and size of the remains relative to the size and strength of the scavenger.[18] Knight pointed out that foxes can drag body parts away to a distance of at least 3 km.[20] The potential movability of a corpse will increase as scavenging progresses and more soft tissue is removed. Topography, stabilization by vegetation or partial burial may also place constrains upon scattering of the remains.[16] Distances that bones can be transported depend upon the size and strength of the involved scavengers. In the cases described above, skeletal elements were recovered from distances ranging from a few meters from the body to approximately 200 m. In Case 3, scattering of bones over a considerable distance compromised the recovery efforts, causing later a problem in re-associating the skeletons.

Taphonomic factors other than scavenging such as rolling down and transport of skeletal elements by sedimentation or by rains may be responsible for the movement of bones.[18,21] Rolling downslope following natural disarticulation seems to be the most probable cause for the movement of the cranium in Case 2.

3.2. Alteration of skeletal elements

Carnivores gnaw bones in patterned ways.[22] The spectrum of the potential damage due to different carnivores ranges from tooth marks, crushed edges at damaged areas, broken off portions, and absence as a result of digestion. From the patterns of tooth marks inflicted on the examined bone surfaces it is suggested that post-mortem skeletal damage was made by small or medium-sized canids. Foxes or dogs are the most likely agents of damage on bones. According to many authors, four types of carnivore tooth marks are in general recognized: punctures, furrows, pitting, and scoring.[17–19,22]

Punctures are oval penetrations through cortex produced when bone collapses under the pressure of a tooth cusp. They are commonly made on the weakest surface of the bone. Both the canine and carnassial teeth can produce punctures. Heavy gnawing may obliterate puncture marks as cancellus tissue is eaten away.[17] However, puncture marks may still be visible close to the margins of the damaged areas as was seen on certain bones in Case 3 and Case 4.

Punctures are the initial stages of furrowing, a term adopted by Haynes.[22] Furrows are produced by the repeated jaw action of either canine or carnassial teeth.[17] Deep furrowing into the cancellous bone may be noted even after the removal of the cortex in long bone ends (Case 3). The result of extreme furrowing is called “scooping out” and involves the removal of the cancellous tissue and licking out its contents from open-ended shafts. When a bone is punctured back from the transverse edge, a channel may be left running parallel to the longitudinal axis of the bone. The proximal end of the right 3rd metacarpal in Case 4 presented typical “channeled” breakage.

Gnawing activity on harder bone shafts produces irregular indentations caused by the tips of the teeth or short linear scratches in the surface of the bone. According to Binford pitting generally results from gnawing bones rather than eating and pulling meat from them.[17] Scoring marks result when carnivores slip their teeth over bone and appear as sets of parallel scratches, V-shaped or U-shaped in cross-section, running perpendicular to the long axis of the bone.

Crushed and fragmented bones may be the result of carnivore activity. Bone fragments and small bones may be swallowed and later regurgitated or passed out with the feces. Boglioli et al. reported a case of a father who murdered his neonate baby and afterwards dismembered the corpse and fed it to the family dog.[23] Radiological examination of the dog revealed numerous bone fragments in its stomach. Bone fragments that have passed through the digestive tract display corrosive damage caused by the action of gastric acids.[24] Their broken edges appear very thin and sharp.[25] Hair, teeth, finger or toe parts, and small bone fragments discovered from carnivore feces have been also reported.[24,26–29] According to Pickering, systematic search and examination of scat deposits may be useful in the identification of human remains.[24]

3.3. Survivorship of skeletal elements

The character of the surviving skeletal remains is determined by the extent to which bones have been processed by carnivores.[30] However, intrinsic bone factors such as the relative proportion and distribution of cortical to cancellus bone, the age and certain pathological conditions affecting density, influence the differential survival and susceptibility to modification of certain bones over others.[30]

The damage to skeletal elements seems to occur during the consumption of soft tissues that cover bones, and during the deliberate consumption of cancellous bone. Crania are usually

found from all scavenged remains. Puskas and Rumney suggested that the head is less scavenged when the whole body is available, as the scavenger may show preference for the torso and extremities.[31] Mandibles may also be damaged by scavengers as was seen in Case 4. Hyoids are recovered rarely because they are swallowed during the consumption of the anterior neck organs.[1,2]

Axial skeletal elements are generally found scattered close to the original body location. Vertebrae, having irregular shapes, are most commonly gnawed on the bodies, the spines and transverse processes. Anterior aspects of vertebral bodies may be chewed with cancellous bone exposed, as was seen in Case 1 and Case 2. The sacrum is usually gnawed at the inferior end, while the coccyx is usually not recovered having been completely consumed. Sternum and sternal rib extremities are also damaged during the destruction of the ventral thorax when accessing the internal organs.

The upper and lower limb elements are most likely to be damaged during scavenging activity. Scapulae are chewed away at the acromion and coracoid process. Scapular damage to the acromion may also affect the acromial end of the ipsilateral clavicle. Iliac crests, ischial tuberosities, and pubic symphyses are the primary areas of damage to innominate bones. The articular ends of long bones are destroyed as the animal chews through the cortex and consumes the cancellus bone which is more attractive to scavengers since it is rich in hemopoietic tissues.[18,23,32,33] However, the loss of long bone ends is seen when there is a period of feeding on the remains.[34] When the articular ends are removed, there is a progressive destruction of the shaft, which can be totally destroyed or survive as a "cylinder".[11] This pattern of damage was recognized in the left ulna in Case 1. The anatomical parts of the humerus that are most likely to be destroyed are the head, the lateral and medial epicondyles, the capitulum, and trochlea. The olecranon process of the ulna might be chewed away. Femora are chewed at the head, greater trochanter and both condyles. Tibiae are most often destroyed at the proximal end. Hands and feet are the most frequently missing anatomical parts, probably due to carnivore activity or because they are often left behind during the recovery effort, especially by inexperienced investigators.[35,36] Shoes may act as a barrier to scavengers, protecting the foot bones, as was observed in Case 1.

Although scavengers may cause a general confusion of the evidence available at the scene, recovery methods may also play a role in determining the extent of the remains retrieved. In the cases described human remains have been recovered by the police. Since police investigators are not trained in the basic recognition of human bones and recovery techniques, body retrieval is usually incomplete. In such cases it is not possible to know which of the scavenged remains were present and survived. Having an anthropologist as a member of the recovery team is essential to ensure that all the skeletal elements and maximum contextual information are collected (W.D. Haglund, personal communication, March 10, 2006). Finally, in the cases presented, the incomplete recovery of the remains impeded the evaluation of the impact that scavenging had on the estimation of the postmortem interval. It is well known that carnivore scavenging may modify the rate of decomposition, the succession pattern of corpse-feeding insects, and the context of associations, thus altering estimations of the postmortem interval.[11]

3.4. Alteration of indicators of cause and manner of death and/or personal identification

Carnivore scavenging may produce widespread damage, often obscuring cause and manner of death, and may also complicate personal identification.[37–39]

According to certain authors open wounds resulting from antemortem trauma can be extensively altered or even obliterated after death.[11,34] The gnawing damage observed on the right innominate in Case 3 altered the morphology of the perimortem pubic ramus fracture. Galloway pointed out that scavenging activity in the pelvic girdle complicates the assessment of injuries.[40]

Skin and soft tissue loss from the face and neck region can also make visual identification impossible.[5,15]

In conclusion, carnivore scavenging is an important factor affecting the postmortem fate of human remains recovered from outdoor locations. Although the effects of animal gnawing have been reported in the past as case studies, a more systematic examination will provide a better understanding of this activity. In turn, this knowledge will benefit death investigations where scavenging is involved.

Conflict of interest

The author has declared that there is no conflict of interest.

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Ethical approval

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